THE PHYSICAL AND CHEMICAL MONITORING OF PERMETHRIN SPRAY DRIFT FROM AERIAL SPRAYING

1985

Ministry of the Environment

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THE PHYSICAL AND CHEMICAL

MONITORING OF PERMETHRIN

SPRAY DRIFT FROM AERIAL SPRAYING

Intergovernmental Relations
and Hazardous Contaminants
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Finally, I would like to extend a special word of thanks to our pilot, K. Chute.

FOREWORD

The Provincial Pesticides Control Program is designed to provide for an acceptable balance between the beneficial uses of pesticides and the protection of environmental health and the natural environment. The Ministry of the Environment has directed research on pesticides through the Ontario Pesticides Advisory Committee based on three objectives: the need to find suitable replacements for pesticides deemed hazardous and restricted for use in Ontario; the need to determine if pesticides in use pose any serious environmental hazard; and the need to develop more effective approaches to pest control leading to a reduction of pesticide input into the environment.

Pesticide chemicals continue to be the first line of defence against crop destroying pests. In order to be able to continue using many of the valuable materials available, safe application procedures must be developed and followed. The procedures must include not only protection from airborne drift damage to near-by non-target crops, but also ensure that applicators, near-by and re-entering workers, human and animal habitat and the local ecosystem will not be adversely affected by the chemical's use.

Great advances have been and continue to be made in the development of new chemicals and formulations. However, application practices have not always kept pace or been given the support necessary to ensure proper application procedures for these chemicals. Today, the problem exists that more stringent regulations on chemical procedures and types of machines may severely limit or even disallow the use of many good materials.

The aerial application of pesticides is well regulated in Ontario under the Pesticides Act. However, there is still concern regarding spray drift from the aerial application of pesticides, particularly when the more toxic and hazardous pesticides are used. For these reasons, a field monitoring study was carried out to generate data on the spray drift from the aerial application of permethrin.

INTRODUCTION

Permethrin (AMBUSH ®), 3-phenoxybenzyl-cis, trans-2, 2-dimethyl-3-(dichlorovinyl) cyclopropane carboxylate, is a synthetic pyrethroid insecticide, which was discovered at Rothamstead, England by the National Research and Development Corporation. In Canada, it is formulated and sold by Chipman Incorporated.

Permethrin is a valuable insecticide, from the farmer's point of view, because it has a much wider margin of human safety than some of the currently registered alternatives for aerial application, such as Guthion, Parathion and Monitor.

Although it has low mammalian and avian toxicity, it has an extremely high level of contact activity against a broad spectrum of insect pests. In addition, it has a useful repellent action against certain species of Lepidoptera, Hemiptera, Orthoptera and Diptera. However, it does not show any systemic or fumigant activity. In laboratory studies, permethrin has been shown to be relatively toxic to aquatic organisms and care must be taken with its use to prevent damage to the aquatic environment.

Since permethrin is such a biologically active chemical, it is not currently registered for application by aircraft. Aerial application of pesticides has many advantages, for example, large areas can be sprayed on a remedial basis very rapidly (up to 4 ha/min). In addition, there is no crop damage and good coverage of the leaf surface. The major disadvantage is the potential for off-target drift into sensitive areas. Despite more than two decades of research directed toward minimizing such drift of agricultural chemicals, it remains the major environmental concern in aerial application.

Because of its undoubted value, Agriculture Canada granted a temporary registration for the aerial use of permethrin on green beans and potatoes in Ontario, but only for 1984. This temporary registration was contingent upon a monitoring program, which would generate data required to measure extent and amount of off-target drift and possible contamination of water in a major watershed.

TERMS OF REFERENCE FOR THE STUDY

The study was to provide additional data on off-target drift of permethrin which will be used for establishing appropriate buffer zones around aquatic ecosystems.

It was conducted to comply, as closely as possible, with requests made by Agriculture Canada, and was designed and carried out over a period of a few weeks. Their requests were as follows:

(1) Several (minimum of 2) potato fields should be used in the monitoring study. These fields must lie 150 m from one or more streams or drainage ditches, which drain into the Notawasaga River.

(2) Drift cards will be placed outside of the treatment area at 50 m intervals from the field margin up to 200 m. "Check" cards should also be placed within the treated field. The cards must be analysed for median droplet diameter and total permethrin residue. If possible, monitoring of both helicopter and fixed-wing (Ag Cat) application methods should be assessed. This aspect of the study will be conducted by Chipman Inc.

(3) Water samples will be collected at a site closest to the field and at various downstream sites within the

stream. This portion of the study will be conducted by the Ontario Ministry of the Environment, Hazardous Contaminants and Standards Branch. Some fish samples will also be collected (max. 10) by the Ontario Ministry of Natural Resources, Environmental Dynamics Section. These samples will be analysed for total permethrin residues by the Ontario Ministry of Agriculture and Food, Pesticide Residue Laboratory. Since the registration includes three possible applications, water samples should be taken 7 days and 1 month after the last application.

THE STUDY

Two typical potato farms were chosen for the study in the Nottawasaga watershed. On each farm the potato field was 60 m away from an adjacent creek draining into the Nottawasaga River; this area was established as the buffer zone.

Two permethrin applications (8 days apart) were made using a Pawnee-D aircraft. At each field, the amount of pesticide hitting the target crop and the amount of off-target drift were monitored by drift cards and soil samples. The drift cards were analysed for total permethrin residue and volume median diameter. The soil samples were also analysed for permethrin residues. Water contamination was measured by residue analysis of water, sediment and fish from the nearby creeks.

Site Description

Approximately one-third of Ontario's potato crop is grown in the Alliston region, representing about 5,261 hectares. The majority of the farms are large-scale operations ranging from 120 - 200 hectares. Pesticides are regularly applied by aircraft in this area.

Two typical farms were used for the monitoring study; they are located in the Nottawasaga watershed in Tecumseth Township, Simcoe County, which drains about 334 km^2 of the Alliston area (Fig. 1).

Site 1

Site 1 was located on Lot 6, Conc. 10, Tecumseth Township. Six hectares (approximately 160 m x 400 m) of the total 18 hectare potato field were treated.

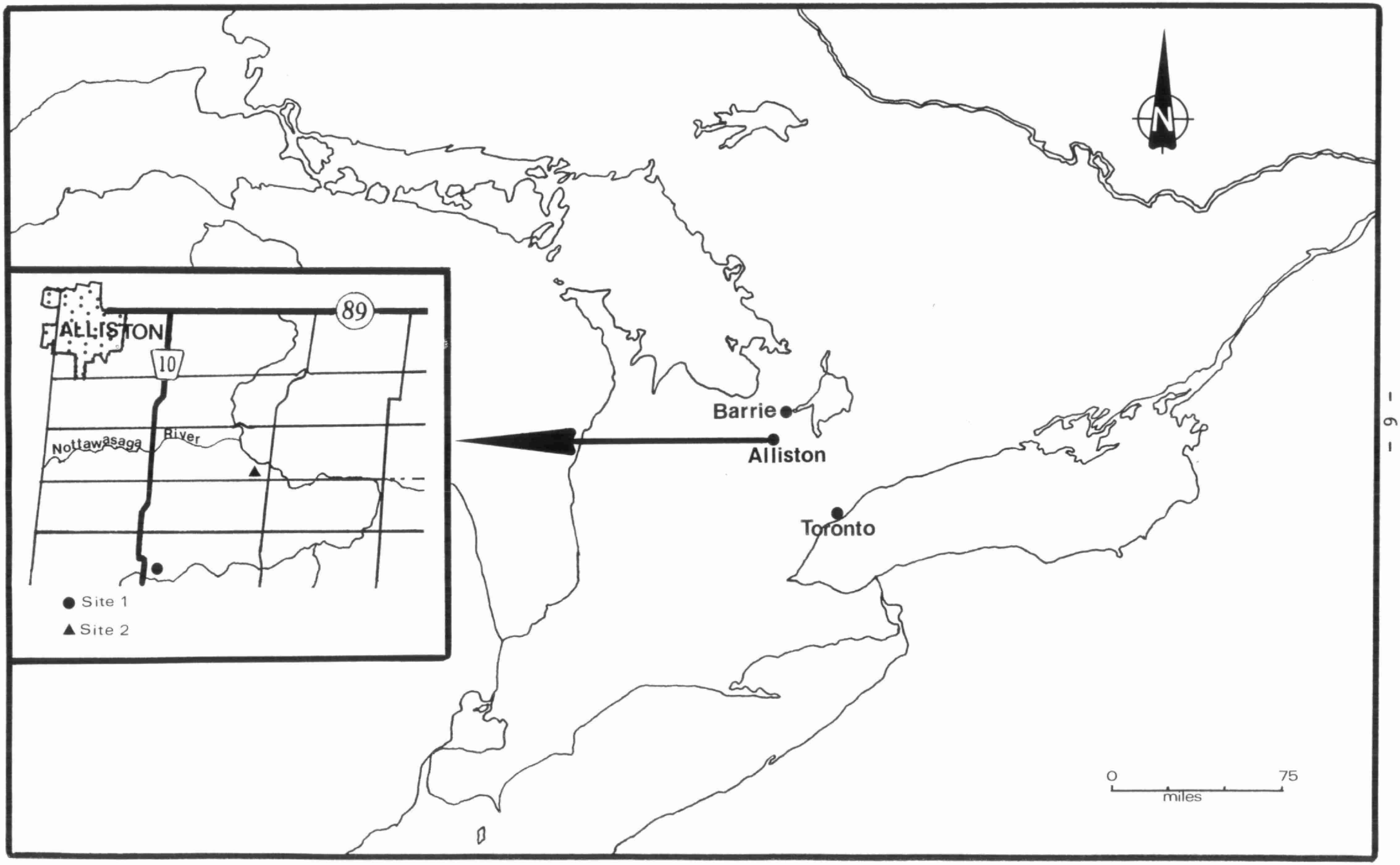

Figure 1. Locations of the two farms chosen for the monitoring study.

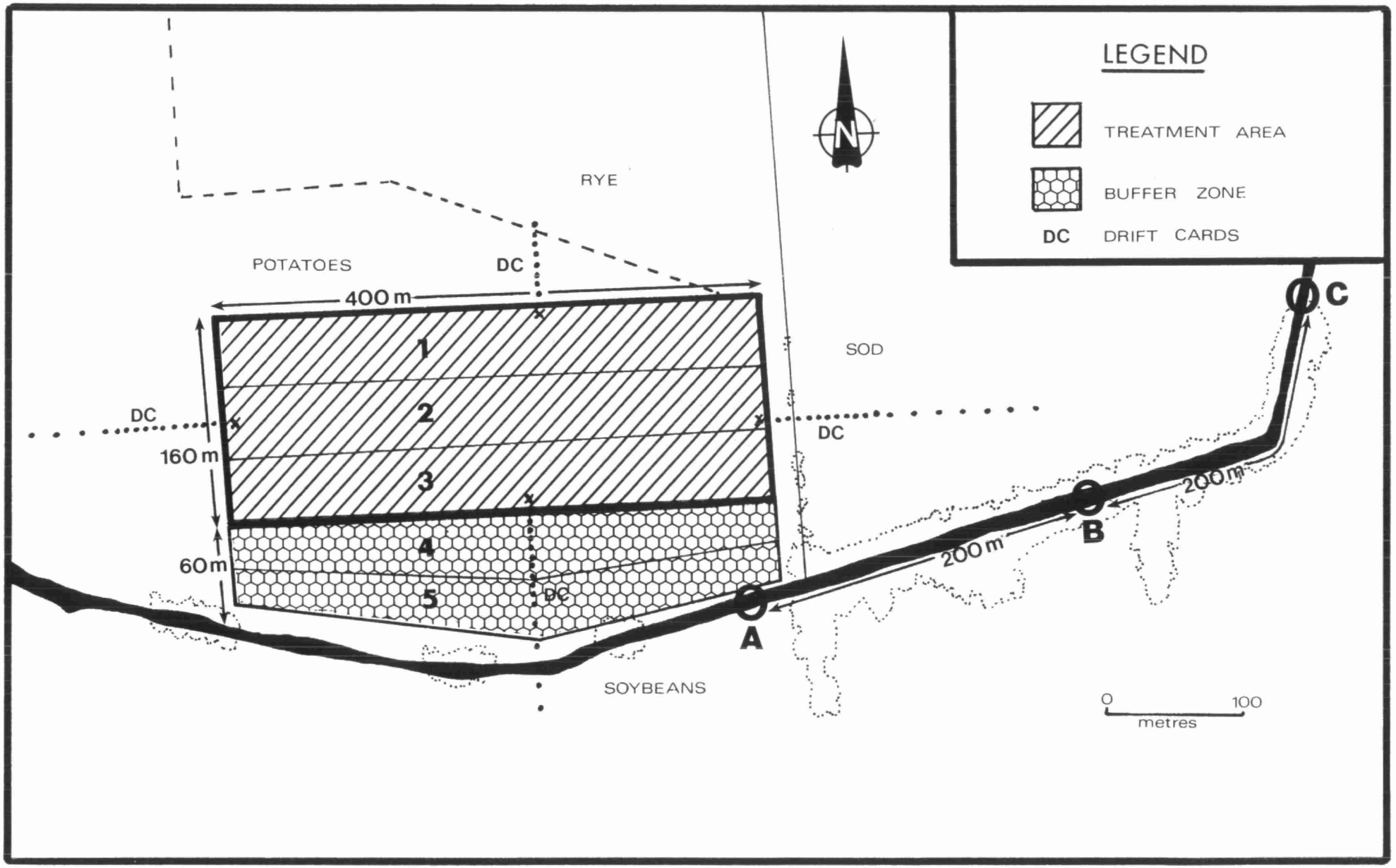

Figure 2. Sampling set-up & locations for Site 1.

A 60-m unsprayed buffer zone was established to protect the stream at the south edge of the treatment plot (Fig. 2).

The treated plot was divided into three equal sections each 53 m X 400 m for soil sampling purposes; these sections were labelled 1, 2 and 3 from north to south. The buffer zone was divided into 2 equal sections (4 and 5) each 27 m x 400 m (Fig. 2).

The Bailey Creek flowed in an easterly and northeasterly direction at first parallel to and to the south of the treated area. There were no obstructions such as trees or brush, etc. between the treatment area and the stream. The bank of the stream was approximately 2 m above the water and was mostly covered with grass (Fig. 3).

Figure 3. Bailey Creek, Tecumseth Township, Simcoe County, 1984.

Table 1. Water quality parameters for the Bailey Creek (Site 1)

	PRE-TREATMENT	FIRST APPLICATION	SECOND APPLICATION
Conductivity (UMHO/cm at 25°C)	440.00	440.00	480.00
Hardness, Total (mg/l as $CACO_3$)	-	-	234.00
Alkalinity, Total (mg/l as $CACO_3$)	194.70	195.60	215.80
pH	8.24	8.24	8.38
Chloride, UNF, Reactive (mg/l as Cl)	10.95	11.02	10.93
Residues, Total (mg/l)	261.00	259.60	-
Residue, Particulate (mg/l)	20.91	15.54	7.79
Turbidity (FTU)	6.80	10.90	6.90
Phosphorus, UNF, Total (mg/l as P)	-	-	0.016
Phosphates, FRAC, React (mg/l as P)	-	-	0.003
Nitrogen, Total KJELD, UNF, R (mg/l as N)			0.30
Ammonium, Total, FRAC, Reac	0.008	0.01	0.004
Nitrates, Total, FRAC, Reac (mg/l as N)	0.27	0.28	0.25
Nitrite, FRAC, React (mg/l as N)	0.0015	0.002	0.005
Dissolved Organic Carbon (mg/l as C)	3.90	3.80	3.70
Dissolved Inorganic Carbon (mg/l as C)	47.50	48.00	52.50

The water quality analysis of Bailey Creek (Site 1) is shown in Table 1. Turbidity and residue particulate were about 8.5 FTU and 14.74 mg/l, respectively. Values of pH ranged from 8.24 to 8.38 and readings for total alkalinity and hardness were on average 194.7 and 234.0 mg/l $CaCO_3$, respectively. These conditions were typical for the Nottawasaga watershed (Rivers Unit, Ministry of the Environment, 1984. Pers. comm.).

Stream flow measurements are shown in Table 2 and indicate that the Bailey Creek is slow moving. The average depth measured about 0.2 m. The water temperature ranged from 21°C to 26°C during application.

The first water and sediment sampling station was located in the creek opposite the southeastern corner of the treatment plot. The second and third sampling stations were 200 m and 400 m respectively downstream from the first station (Fig. 2).

Site 2

Site 2 was located at Lot 10, Conc. 12, Tecumseth Township. About 6 hectares (approximately 400 m x 120 m) of the total 30 hectare potato field were treated.

Two 60 m wide unsprayed buffer zones were established to protect the stream, one at the eastern edge and the other at the northern edge of the treatment plot (Fig. 4). In both buffer zones, a strip 45 m wide was planted with potatoes; the remaining 15 m to the creek was a woodlot.

The treatment plot was divided into three equal sections, each 40 m x 400 m, again for soil sampling purposes; these sections were designated as sections 1, 2 and 3 from south to north. The portion of the buffer zone planted with potatoes at the northern edge of the treatment plot

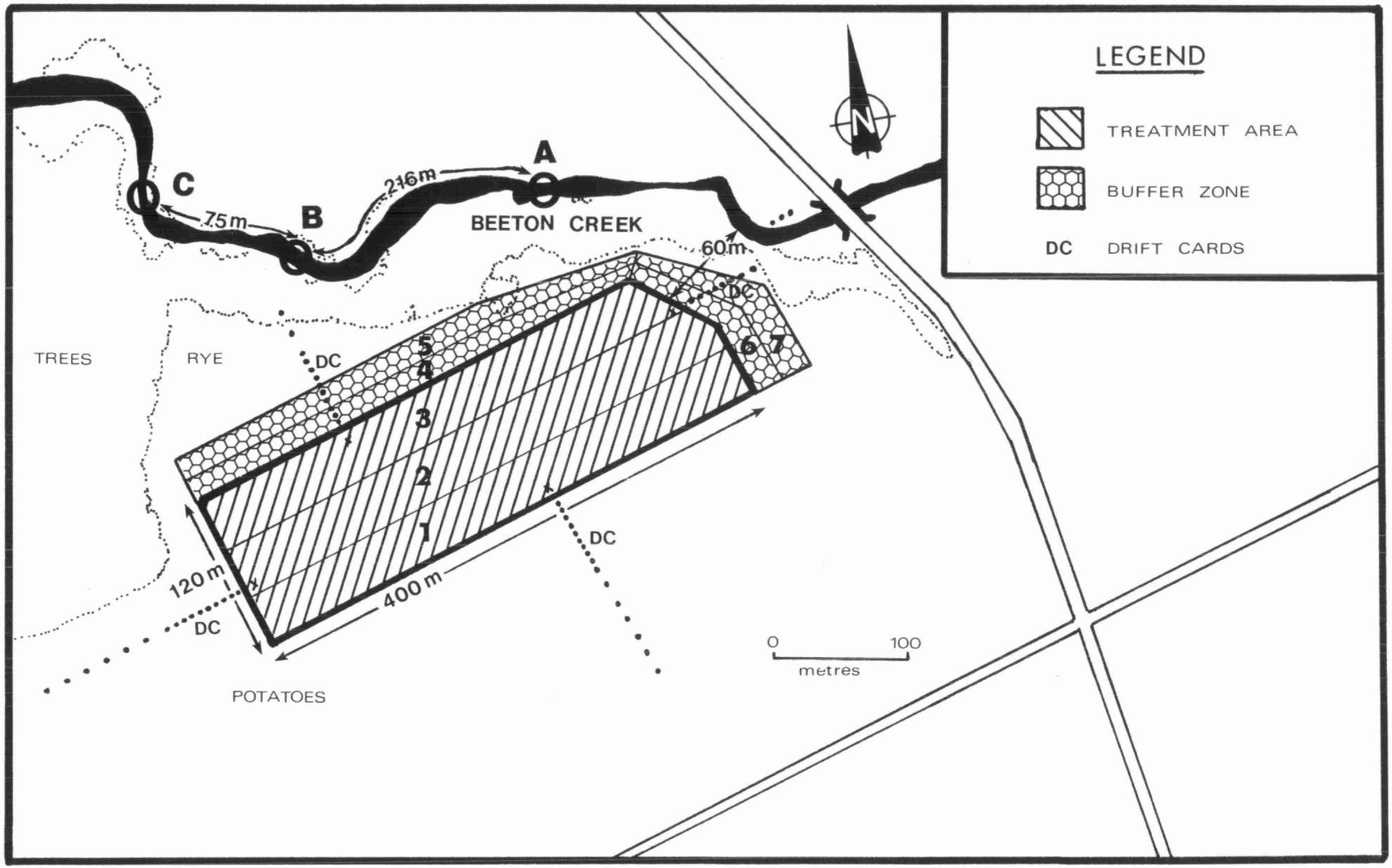

Figure 4. Sampling set-up & locations at Site 2.

Table 2. Stream flow measurements taken during both permethrin applications at the Bailey Creek and Beeton Creek.

CREEK	APPLICATION	STREAMFLOW (m^3/sec)	AREA (m^2)	MEAN VELOCITY
Bailey Creek	1	0.14	0.68	0.20
	2	0.18	0.65	0.28
Beeton Creek	1	0.34	1.18	0.29
	2	0.42	1.14	0.30

was divided into two equal sections measuring 23 m x 400 m; these sections were numbered 4 and 5. Similarly, the planted portions of the buffer zone at the eastern edge of the treatment plot was divided into two equal sections measuring 23 m x 400 m; these sections were labelled 6 and 7 (Fig. 4).

The Beeton Creek flowed in a northwesterly direction about 16 m from the corner of the field. There were some trees and brush between the edge of the potato field and the stream. The top of the bank was approximately 17 m above creek level at the northeast corner of the field (Fig. 5) and declined to about 3 m at the west end of the field.

The water quality analysis of Beeton Creek (Site 2) is shown in Table 3. Turbidity and residue particulate averaged 28.7 FTU and 51.1 mg/l, respectively. Values of pH ranged from 7.92 to 8.34. Values for alkalinity and hardness averaged 210.8 and 238.6 mg/l $CaCO_3$, respectively. These results also represent conditions typical for the Nottawasaga watershed (Rivers Unit, Ministry of the Environment, 1984. Pers. comm.).

Figure 5. Beeton Creek, Tecumseth Township, Simcoe County, 1984.

Stream flow measurements are recorded in Table 2 and indicate that Beeton Creek is slow-moving. The average depth measured was about 0.26 m. The water temperature ranged from 22°C to 26°C.

The first water and sediment sampling station was located in the creek opposite a point about 100 m from the eastern edge of the field; the second and third sampling locations were located 216 m and 291 m respectively further downstream (Fig. 4).

Table 3. Water quality parameters for the Beeton Creek (Site 2)

	PRE-TREATMENT	FIRST APPLICATION	SECOND APPLICATION
Conductivity (UMHO/cm at 25°C)	490.00	495.00	242.00
Hardness, Total (mg/l as $CACO_3$)	235.00	233.00	248.00
Alkalinity, Total (mg/l as $CACO_3$)	201.40	201.50	229.40
pH	7.94	7.92	8.34
Chloride, UNF, Reactive (mg/l as Cl)	18.98	19.00	23.60
Residues, Total (mg/l)	-	-	-
Residue,Particulate (mg/l)	62.97	66.91	23.32
Turbidity (FTU)	31.00	36.00	19.20
Phosphorus, UNF, Total (mg/l as P)	0.103	0.15	0.04
Phosphates, FRAC, React (mg/l as P)	0.02	0.023	0.005
Nitrogen, Total KJELD, UNF, R (mg/l as N)	0.52	0.59	0.46
Ammonium, Total, FRAC, Reac	0.01	0.01	0.02
Nitrates, Total, FRAC, Reac (mg/l as N)	0.68	0.67	0.43
Nitrite, FRAC, React (mg/l as N)	0.002	0.002	0.013
Dissolved Organic Carbon (mg/l as C)	4.00	4.00	4.20
Dissolved Inorganic Carbon (mg/l as C)	49.50	50.50	55.00

METHODS

Insecticide Application

A Pawnee-D plane equipped with 22 model D-110 cone tip T-Jet ® nozzles applied 2.71 g of permethrin per litre to about 6 ha (i.e., 100 g AI/ha or 4 U.S. gal/acre). Each spray load consisted of 22.5 litres of water, 1.22 litres of permethrin (AMBUSH ® 50 E.C.) and a dye. In the first application an Ag Mark P-2 liquid concentrate dye was added to the spray mixture and in the second application a Rhodamine dye (450 g dissolved in 1 litre of acetic acid) was added to the spray tank. The spray boom was approximately 2 m above the crop canopy with a swath width of about 15 m (Fig. 6).

Figure 6. A Pawnee-D aircraft was used to apply the permethrin.

The speed of the aircraft during each application was 155 to 160 kph. About 11 to 12 passes in each direction (east to west) were made. However, during the second application at Site 2, the pesticide was applied in an easterly direction only, due to foggy weather conditions. At both sites the first swath was made at the side of the plot closest to the stream.

Weather conditions, i.e., wind speed and direction, were measured during application with a Texas Instrument sensing head and a digital readout unit (Fig. 7).

Figure 7. A Texas Instrument sensing head was used to measure wind direction and speed.

Drift Card Study

Residue Sampling

Deposits were collected on Whatman #1 filter papers (15 cm diameter) and on Kromekote ® cards (10.1 x 10.1 cm). The filter papers and cards were fastened

to wooden stakes 82 cm high (Fig. 8). A stake was placed (at 6.1 m (20 ft.)) into the plot; further stakes were placed 6.1 m (20 ft.) apart in a straight line outside the plot to a distance of 60 m (200 ft.); and then at 15 m (50 ft.) intervals up to 154 m (500 ft.) (Fig. 2 and Fig. 4).

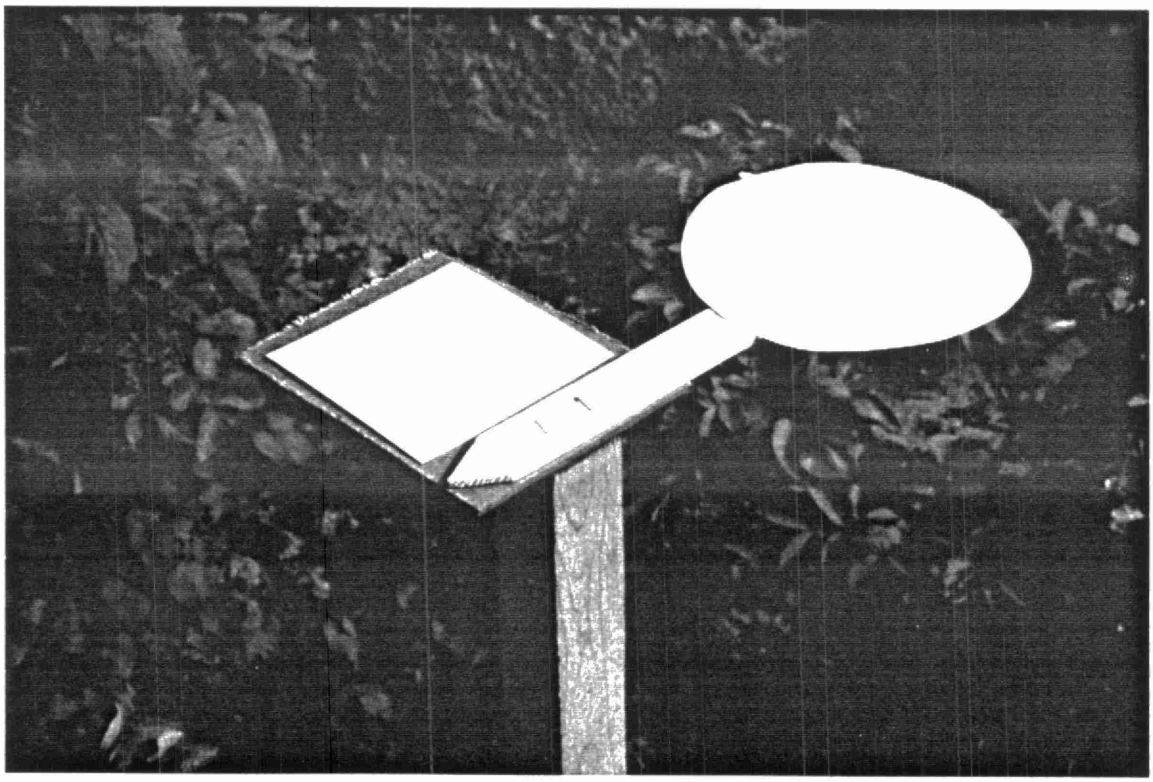

Figure 8. Whatman filter papers and Kromekote ® cards were used to collect insecticide deposit.

Filter papers for both applications and Kromekote ® cards, for second application only, were placed in the field 1 hour before application and were collected within 90 minutes following spraying. The papers were collected beginning with those farthest from the plot to reduce sample contamination. Papers were placed in bottles prewashed with acetone. Care was taken to avoid contamination of the papers by thoroughly washing hands with soap and water and then

rinsing with acetone prior to handling. Samples were kept cool during transport to the laboratory and then kept frozen until extraction.

Deposits on the filter paper were extracted with hexane. The total hexane extract was reduced by rotary evaporation to 5 ml. When necessary, a portion of this was cleaned up on a Florisil column and analysed using a gas chromatograph equipped with an electron capture detector. The limit of detection was 0.1 microgram per filter paper for total isomer content (Appendix 1). Analysis of the filter papers was discontinued when 3 consecutive non-detectable results were obtained.

Droplet Categorization

Droplet deposit was determined using a spot counting system. Each Kromekote ® card was examined using dissecting and compound microscopes. Droplets on the cards were counted and grouped into diameter classes. When categorizing droplet diameter, it was assumed that the diameter of the droplet on the Kromekote ® card was 2 x the diameter of the droplet in the air (Sundaram, 1984. Pers. comm.).

From this data a number median diameter (NMD) and volume median diameter (VMD) was determined. The NMD is the diameter, that divides the number of droplets into two equal groups: i.e., 50% of the droplets have a diameter greater than and 50% smaller than the median. Similarly, the VMD is the droplet diameter that divides the total spray volume into two equal halves: i.e., 50% of the volume falls in droplets larger than the VMD, and 50% in smaller droplets.

Insecticide Residue Analysis Study

One day prior to application duplicate samples of water, sediment, fish and soil were taken at each site to determine the background levels of permethrin. Water quality parameters such as, pH, hardness, turbidity etc. were measured before and after the permethrin applications.

Water Sampling

Surface water samples were collected by submerging a 1-litre wide-mouth bottle approximately 4 cm below the surface of the water in midstream and allowing the bottle to fill. Samples were taken in duplicate at the moment of application, and at 10 and 20 minutes later. The collection times of the last two samples were determined by the flow rate of the water. Stream flow measurements were taken by an Ott Meter using standard methods (Terzi, 1981).

Integrated depth water samples were collected in 1-litre narrow-neck bottles clamped to an 8-m aluminium pole (Miles and Harris, 1973). Depth integration was achieved by moving the bottle from just below the surface to within about 30 cm of the bottom, while the bottle was filling with water (Fig. 9). Duplicate samples were collected at 1/2, 1 and 6 hours post- application. All water samples were sealed with aluminium-foil caps and were kept at about 5°C during transport to the laboratory.

Water samples (2 litres) were extracted immediately upon receipt at the laboratory or were stored at 5°C for not longer than 36 hours prior to extraction. Extraction by partitioning was carried out by shaking for 1 minute with three 100-ml portions of dichloromethane. The dichloromethane extracts were

dried and combined by percolation through anhydrous sodium sulphate, evaporated just to dryness with a rotary vacuum at 50°C, and then re-dissolved in about 5 ml hexane.

Figure 9. An integrated depth water sampler.

Sediment Sampling

Sediment samples were collected in a steel can measuring 8.5 cm in diameter and 4.5 cm deep, which was attached at right angles to the end of an 8-m aluminium pole (Fig. 10). The can was placed gently on the bottom of the stream in an inverted position so as to avoid disruption of the sediment. To take the sample, the pole was rotated through 180° causing the can to scoop up the sediment. Six sediment samples were taken in a line at various distances from the bank to mid-stream and combined into one sample by placing them in a plastic bag. Sediment samples were collected at 6 hours, 1 day and 6 days

after each of the two treatments; samples were also taken at 30 days post-second treatment. All samples were kept at about 5°C during transport to the laboratory.

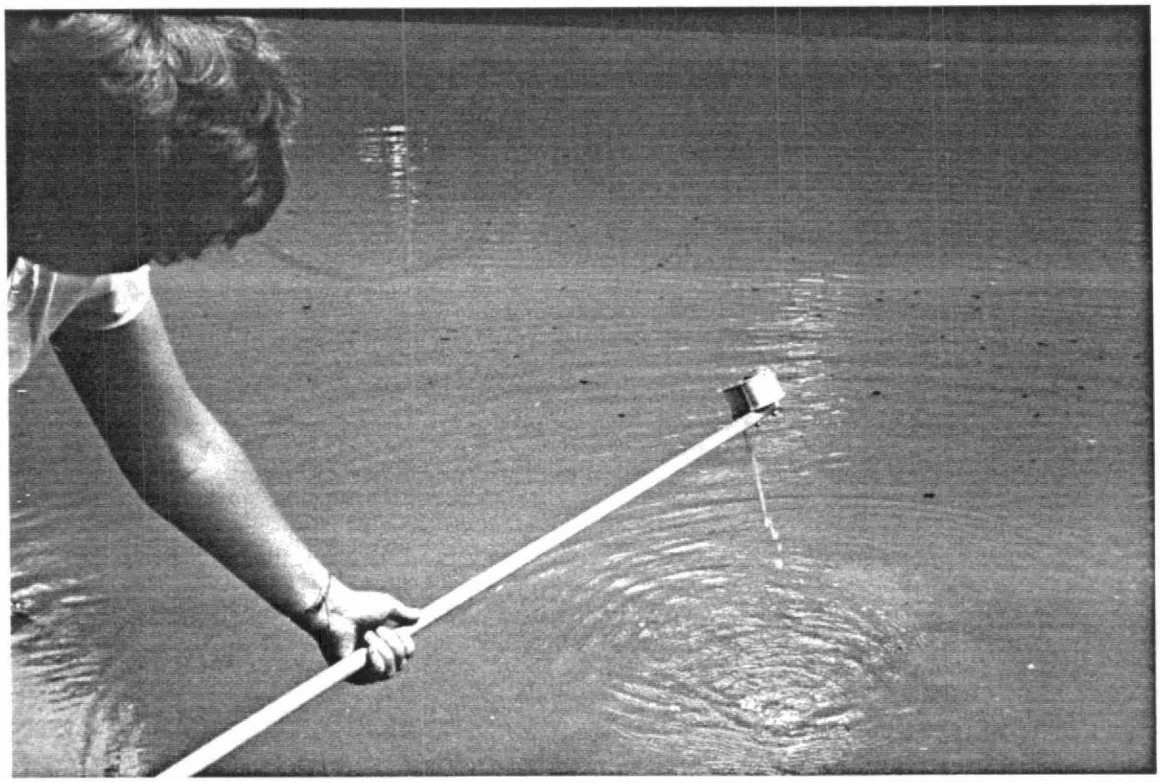

Figure 10. A sediment sampler.

Soil Sampling

Soil samples were collected in a 3-sided homemade steel container measuring about 10 cm x 5.5 cm x 5.5 cm (Fig. 11).

Samples were taken by sliding the open end of the sampler along the top 2.5 cm of soil. Approximately 20 samples were collected at random in each sampling section, and combined into one sample by placing them together in a plastic bag. Soil samples were taken following the same sampling schedule as for the sediment samples.

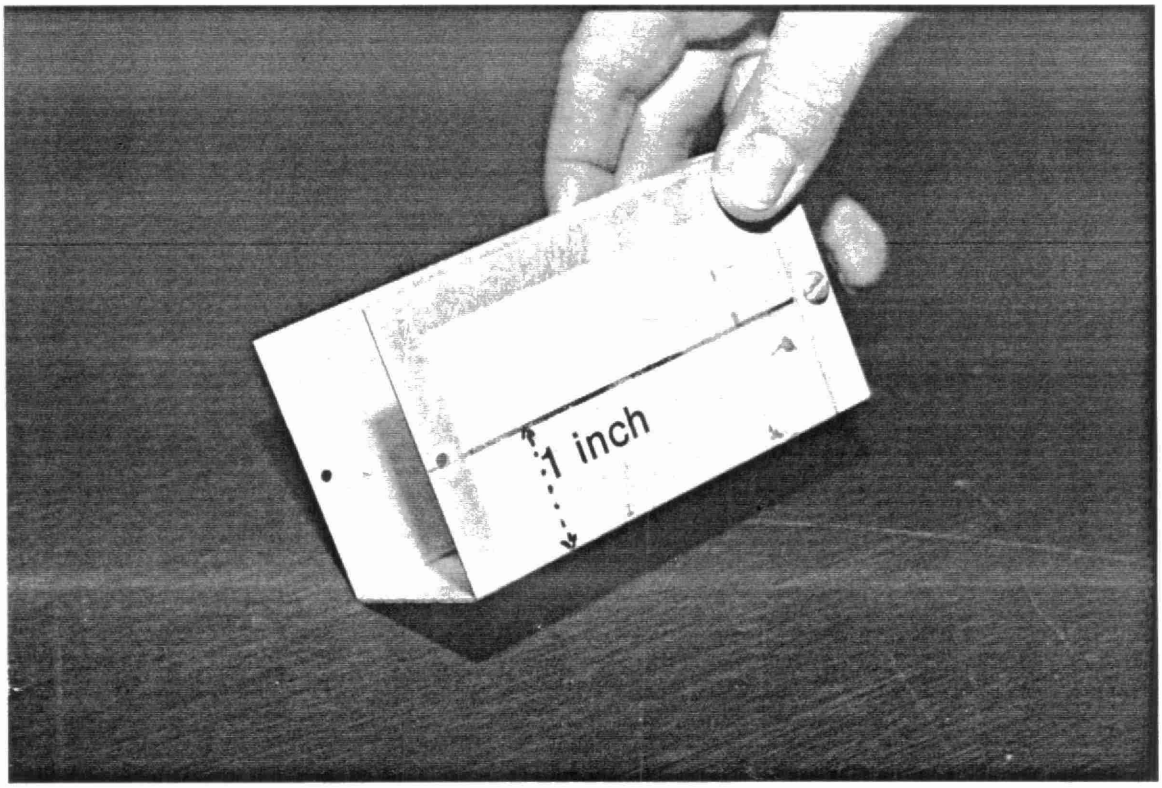

Figure 11. A soil sampler.

Twenty-five gram samples of sediment and soil were each extracted by shaking for 2 hours with 250 ml acetone: dichloromethane. A 10-g sample aliquot was filtered off, shaken for 15 seconds with 300 ml water containing 2% sodium chloride, and the dichloromethane phase was percolated through anhydrous sodium sulphate; the aqueous phase was re-shaken for 1 minute with 50 ml dichloromethane, combined with the first extract, evaporated just to dryness with rotary vacuum at 50°C, and then re-dissolved in about 5 ml hexane.

Fish Sampling

Fish were collected from the section of the stream adjacent to the treatment area using an electro-shocker. Each species was counted and placed in separate plastic bags. The samples were immediately frozen for transport to the laboratory.

Fish samples were macerated in a food chopper and a 20-g sub-sample was extracted by blending for 5 minutes with 200 ml 2:1 acetonitrile:water. Approximately 150 ml of extract was filtered off and placed in a freezer overnight at -20°C for freeze-out of water and lipids. An aliquot of the supernatant acetonitrile extract (equivalent to 10 g sample) was diluted with 300 ml water containing 2% sodium chloride and shaken twice for 1 minute with 100 ml dichloromethane. The dichloromethane extracts were dried by percolation through anhydrous sodium sulphate, evaporated just to dryness with rotary vacuum at 50°C, and then re-dissolved in about 5 ml hexane.

All hexane extracts were cleaned up on Florisil columns and analysed by gas chromotography according to the method described by Braun and Stanek (1982).

Recoveries of permethrin were determined by fortifying water, soil, and fish tissues at levels of 0.05 ppb, 0.1 ppm and 0.1 ppm respectively with respect to both the cis and trans isomers of permethrin. Recoveries of 86% in water, 90% in soil, and 94% in fish were obtained and were based on the average of two determinations. Detection limits for permethrin were approximately 0.005 ppb for water, 5 ppb for soil and sediment, and 10 ppb for fish tissue.

RESULTS AND DISCUSSION

Drift Card Study

Appendix 2 shows the meteorological measurements that were recorded during the applications. Despite good planning and careful interpretation of weather conditions, changes in wind direction could not be predicted; and, in fact, the wind did not blow towards the water in any of the applications.

Insecticide Residues

Results from the permethrin residue analysis of the filter papers collected at Site 1 are shown in Table 4. During the first treatment the wind speed was very low (about 2 mph) and its direction was predominantly towards the northeast (Appendix 2). The maximum distance that permethrin residues were detected outside of the treatment plot was 55 m in an easterly direction. Residues declined very quickly from 16% of that deposited in the target zone at 6.1 m to 0.37% at 55 m.

During the second treatment, the wind speed was about 6 to 7 mph and was blowing predominately towards the northwest. Residues were detected up to 55 m in a northerly direction. Residues again declined very quickly from 7% of those deposited in the target zone at 6.1 m to 0.1% at 55 m.

Results from permethrin residue analysis of the filter paper collected at Site 2 are shown in Table 5. At this site, the wind speed was not measurable (< 2 mph) and its direction was predominantly towards the south during the first treatment. The maximum distance that permethrin residues were detected outside of the treatment plot was

Table 4. Permethrin residue analysis of filter papers collected at Site 1

Sample in ft. from Plot	FILTER PAPER LOCATION FOR FIRST APPLICATION								FILTER PAPER LOCATION FOR SECOND APPLICATION							
	North		East		South		West		North		East		South		West	
	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha
Plot	90.7	51.53	30.5	17.33	104.1	59.09	9.65	5.48	97.8	65.57	54.2	30.79	104.3	59.26	72.5	41.19
20	1.25	0.71	5.02	2.85	N.D.	N.D.	0.20	0.11	7.25	4.12	0.57	0.32	N.D.	N.D.	0.18	0.10
40	0.65	0.37	2.30	6.31	N.D.	N.D.	0.17	0.10	2.40	1.36	0.74	0.40	N.D.	N.D.	0.25	0.14
60	0.28	0.16	1.57	0.90	N.S.	N.S.	N.D.	N.D.	1.29	0.73	0.13	0.07	N.D.	N.D.	N.D.	N.D.
80	N.D.	N.D.	0.69	0.39	N.D.	N.S.	N.D.	N.D.	1.51	0.86	N.D.	N.D.			N.D.	N.D.
100	N.D.	N.D.	0.33	0.19			N.D.	N.D.	0.52	0.30	N.D.	N.D.			N.D.	N.D.
120	N.D.	N.D.	0.20	0.11					0.31	0.18	N.D.	N.D.				
140			0.10	0.06					0.17	0.10						
160			0.16	0.09					0.12	0.07						
180			0.10	0.06					0.12	0.07						
200			N.D.	N.D.					N.S.	N.S.						
250			N.D.	N.D.					N.S.	N.S.						
300									N.S.	N.S.						
350									N.S.	N.S.						
400									N.S.	N.S.						
450																
500																

N.D. = Non-Detectable < 0.1 ug/FP
N.S. = Not sampled due to crop
FP = Filter paper

Table 5. Permethrin residue analysis of filter papers collected at Site 2

Sample in ft. from Plot	FILTER PAPER LOCATION FOR FIRST APPLICATION								FILTER PAPER LOCATION FOR SECOND APPLICATION							
	North		East		South		West		North		East		South		West	
	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha	ug/FP	g/ha
Plot	45.4	25.5	0.69	0.39	77.6	44.09	1.01	0.57	56.6	32.2	30.5	17.3	43.0	24.4	4.19	2.38
20	2.40	1.36	0.67	0.38	2.91	1.65	N.D.	N.D.	0.21	0.12	1.52	0.86	N.D.	N.D.	1.57	0.89
40	0.99	0.56	0.34	0.19	1.20	0.68	N.D.	N.D.	0.21	0.12	0.98	0.56	N.D.	N.D.	1.86	1.06
60	N.D.	N.D.	0.13	0.07	0.54	0.31	N.D.	N.D.	0.13	0.07	0.53	0.30	N.D.	N.D.	2.28	1.30
80	N.D.	N.D.	N.D.	N.D.	0.61	0.35			0.13	0.07	0.20	0.11			1.65	0.93
100	N.D.	N.D.	N.D.	N.D.	0.33	0.19			0.11	0.06	N.D.	N.D.			1.12	0.64
120			N.D.	N.D.	0.21	0.12			0.13	0.07	N.D.	N.D.			0.55	0.31
140					0.19	0.11			N.D.	N.D.	N.D.	N.D.			0.48	0.37
160					0.17	0.10			N.D.	N.D.					0.35	0.20
180					0.12	0.07			N.D.	N.D.					N.D.	N.D.
200					N.S.	N.S.									N.D.	N.D.
250					N.S.	N.S.										
300					N.D.	N.D.										
350					N.D.	N.D.										

N.S. = No sample - sample was destroyed in transit
N.D. = Non-Detectable < 0.1 ug/FP
FP = Filter paper

55 m to the south. However, the two filter papers placed at the next two locations, 61 and 71 m were not analysed because they were destroyed in transit. Residues declined very quickly from 4% of those deposited in the target zone at 6.1 m to 0.15% at 55 m.

During the second application, the wind speed was not measurable (< 2 mph) and its direction could not be determined either. Nevertheless, residues were detected up to 49 m in a westerly direction. These deposits may have been caused in part by the venturi effect of the passing aircraft. Residues again declined very quickly from 37% of those deposited in the target zone at 6.1 m to 8% at 49 m.

The method of application used in our study was typical for treatment of potatoes, e.g., Pawnee-D aircraft, cone-tip nozzles, wind speed of 2 to 7 mph, application parallel to rows, etc. Results from both farms showed that the concentration of permethrin drifting outside the treatment area was low (0.07 g/ha was detected at 55 m). Therefore, under these conditions in typical commercial applications, low levels of permethrin would be expected to drift.

Droplet Categorization

The droplet categorization at Site 1 is shown in Table 6 and Appendix 3 (Tables A3-1 to A3-4). The maximum distance from the treatment area that droplets were detected was 61 m to the west, where the number of droplets was 0.009% of the number deposited in the treatment area. Wind was towards the north west at a maximum of 7 mph.

The droplet categorization at Site 2 is shown in Table 7 and Appendix 3 (Tables A3-5 to A3-8). The maximum distance from the treatment area that droplets were detected was 61 m to the west, where the number of droplets was 0.3% of the number deposited in the treatment area. The wind was not measurable either in direction or speed, during the Site 2 application; however, droplet deposition was detected in southerly and easterly directions (both towards Beeton Creek), but not to the south.

If, for comparison purposes, the data from the droplet categorization study was reversed in direction to allow for a collective wind direction towards the creeks, then the maximum droplet migration distance of 61 m would not be far enough to allow for entry of pesticide droplets into the adjacent surface waters.

In order to minimize drift, it is important to try to eliminate very small droplets and to apply the pesticide during low wind speeds (Akesson and Yates, 1964; Yates et al., 1978; Ware, et al., 1969). For example, some researchers have found that a 100 um droplet will be displaced 11.5 m by a 3.6 km/hr wind; whereas, the same size droplet will be displaced 45.7 m in a 24 km/hr wind (Jacobsen, 1984). In our study, the VMD's of the droplets out to 61 m in wind speeds ranging from 2 to 7 mph, generally were < 100 um. Therefore, if the spray volume containing < 100 um droplets could be reduced or even eliminated, the distance that permethrin would drift off target would be dramatically reduced.

Table 6. Droplet number and distribution according to diameter category at Site 1, second application.

Sample in ft. from Plot	NORTH # of droplets/ cm^2	NORTH VMD (um)	EAST # of droplets/ cm^2	EAST VMD (um)	SOUTH # of droplets/ cm^2	SOUTH VMD (um)	WEST # of droplets/ cm^2	WEST VMD (um)
Plot	56.1	250	49.0	260	57.93	330	108.0	250
20	2.91	100	0.34	85	N.D.	N.D.	0.05	63
40	0.17	180	0.22	110	N.D.		0.03	80
60	1.62	88	0.08	100	N.D.		0.04	110
80	1.02	74	0.04	95	N.D.		0.11	110
100	0.42	150	0.02	100	N.D.		0.05	130
120	0.13	70	0.03	80	N.D.		0.02	100
140	0.15	75	0.03	80	N.D.		0.03	90
160	0.06	55	N.D.	N.D.	N.D.		0.05	120
180	0.24	80	N.D.		N.D.		N.D.	N.D.
200	N.D.	N.D.	N.D.		N.D.		0.01	
250	N.S.	N.S.	N.D.		N.D.		N.D.	
300	N.S.		N.D.		N.D.		N.D.	
350	N.S.		N.D.		N.D.		N.D.	
400	N.S.		N.D.		N.D.		N.D.	
450	N.S.		N.D.		N.D.		N.D.	
500	N.S.		N.D.		N.D.		N.D.	

Table 7. Droplet number and distribution according to diameter category at Site 2, second application.

Sample in ft. from Plot	NORTH # of droplets/ cm^2	NORTH VMD (um)	EAST # of droplets/ cm^2	EAST VMD (um)	SOUTH # of droplets/ cm^2	SOUTH VMD (um)	WEST # of droplets/ cm^2	WEST VMD (um)
Plot	116.75	240	41.0	170	37.75	250	53.6	120
20	0.02	60	14.5	40	N.D.	N.D.	15.5	65
40	0.32	44	19.5	58	N.D.	N.D.	13.25	65
60	0.05	54	2.75	82	N.D.	N.D.	13.5	55
80	0.13	48	0.29	30	N.D.	N.D.	18.25	65
100	0.03	38	N.D.	N.D	N.D.	N.D.	13.75	75
120	N.D.	N.D	N.D.	N.D	N.D.	N.D.	10.0	60
140	N.D.	N.D	N.D.	N.D	N.D.	N.D.	8.25	35
160	N.D.	N.D	N.S.	N.S	N.D.	N.D.	1.55	25
180	N.D.	N.D	N.S.	N.S	N.D.	N.D.	0.29	45
200	N.D.	N.D	N.S.	N.S	N.D.	N.D.	0.16	20
250	N.D.	N.D	N.S.	N.S	N.D.	N.D.	N.D.	N.D.
300	N.D.	N.D	N.S.	N.S	N.D.	N.D.	N.D.	N.D.
350	N.S.	N.S	N.S.	N.S	N.D.	N.D.	N.D.	N.D.
400	N.S.	N.S	N.S.	N.S	N.D.	N.D.	N.D.	N.D.
450	N.S.	N.S	N.S.	N.S	N.D.	N.D.	N.D.	N.D.
500	N.S.	N.S	N.S.	N.S	N.D.	N.D.	N.D.	N.D.

Insecticide Residue Study

Soil Analysis

The soil residue data confirmed the drift card data by indicating that drift into the buffer zone did occur. Results from the residue analysis of the soil at both sites are summarized in Table 8. Permethrin residues from the soil within the treatment areas ranged from 580 ug/kg to non-detectable (< 5.0 ug/kg) over the 30-day sampling period. Pesticides residues in the soil of the buffer zone at Site 1 were 3% of those in the treatment area after 6 hours, but only 0.56% after 6 days. However, at Site 2 only one buffer zone sample showed a detectable residue (11 ug/kg or about 3% of the average concentration of the treated area), the remainder were non-detectable.

The amount of insecticide in the treated soil declined to about 2% of the initial post-treatment value within 30 days at Site 1. The observation is supported by other persistence studies conducted on plainfield sand and mineral soil (Kaneko et al., 1978; Williams and Brown, 1979; Chapman and Harris; Harris et al., 1981).

Table 8. Residue levels (ug/kg) detected in soil from Site 1 and Site 2

	FIRST TREATMENT			SECOND TREATMENT				
	PRE-TREATMENT	POST-TREATMENT		PRE-TREATMENT	POST-TREATMENT			
		6-hr	1-day	1-day	6-hr	1-day	6-day	30-day
SITE 1								
Treatment 1	ND	160	170	120	410	180	220	ND
Area 2	ND	170	460	160	340	580	160	15
3	ND	110	330	87	270	110	150	8
Buffer 4	ND	ND	ND	ND	14	ND	6	ND
Zone 5	ND	ND	ND	ND	8	ND	ND	ND
SITE 2								
Treatment 1	ND	190	300	22	450	170	-	-
Area 2	ND	380	230	7	410	320	-	-
3	ND	130	360	56	190	120	-	-
Buffer 4	ND	ND	ND	ND	11	ND	-	-
Zone 5	ND	ND	ND	ND	ND	ND	-	-
6	ND	ND	ND	ND	ND	ND	-	-
7	ND	ND	ND	ND	ND	ND	-	-

ND : non-detectable < 5.0 ug/kg
- : not sampled because the land had been disced.

Water and Sediment Analysis

The formulation of permethrin used in this study has a density similar to water, and is essentially nonsoluble in water. Due to these physical

properties, when permethrin falls on a slowly moving water system a surface film will form. Therefore, the likelihood of the bottom sediment and fish being exposed to the pesticide is significantly reduced. This was confirmed by the results from the residue analysis of water, sediment and fish collected from the Bailey Creek and Beeton Creek.

After the first treatment at Site 1, residues in the Bailey Creek were below the detection limit, i.e., < 0.005 ug/l, at sampling stations 1 and 2. At station 3, permethrin concentrations in surface water were 0.008 ug/l, taken ten minutes after treatment (Table 9). Residues were non-detectable in the water samples at all three sampling stations after the second permethrin treatment.

Six hours after the first treatment at Site 1, accumulations of permethrin in sediment were low (ranging from 18.1 to 21.1 ug/kg) and persisted for less than one day (Table 10).

At Site 2 (Beeton Creek) there was a dispersion of the insecticide below the surface of the water after the first application. However, this dispersion was limited i.e., 0.017 and 0.018 ug/l at stations 1 and 3, six hours after treatment (Table 11). It was probably induced by the turbulence of the water, since this creek was deeper and the water velocity was greater than in Bailey Creek.

Table 9. Residue analysis results for surface and integrated depth water samples (ug/l) taken from Bailey Creek (Site 1)

	SAMPLE TIME	SAMPLE TYPE	FIRST TREATMENT	SECOND TREATMENT
STATION 1	Pretreatment	I	ND	ND
	0 min.	S	ND	ND
	10 min.	S	ND	ND
	20 min.	S	ND	ND
	1/2 hour	I	ND	ND
	1 hour	I	ND	ND
	6 hour	I	ND	ND
STATION 2	Pretreatment	I	ND	ND
	0 min.	S	ND	ND
	10 min.	S	ND	ND
	20 min.	S	ND	ND
	1/2 hour	I	ND	ND
	1 hour	I	ND	ND
	6 hour	I	ND	ND
STATION 3	Pretreatment	I	ND	ND
	0 min.	S	trace	ND
	10 min.	S	0.008	ND
	20 min.	S	trace	ND
	1/2 hour	I	ND	ND
	1 hour	I	ND	ND
	6 hour	I	ND	ND

S : surface water sample
I : integrated depth water sample
ND : non-detectable < 0.005 ug/l
P : pre-treatment sampling
- : sample not taken

Table 10. Residue analysis results for sediment samples (ug/kg) taken from Bailey Creek (Site 1)

	FIRST TREATMENT			SECOND TREATMENT				
	PRE-TREATMENT	POST-TREATMENT		PRE-TREATMENT	POST-TREATMENT			
	1-day	6-hr	1-day	1 day	6-hr	1-day	6-day	30-day
STATION 1	ND	20.7	ND	ND	ND	ND	ND	ND
STATION 2	ND	21.1	ND	ND	ND	ND	ND	ND
STATION 3	ND	18.1	ND	ND	ND	ND	ND	ND

ND : non-detectable < 5.0 ug/kg
- : sample not taken

Table 11. Residue analysis results for surface and integrated depth water samples (ug/l) taken from Beeton Creek (Site 2)

	SAMPLE TIME	SAMPLE TYPE	FIRST TREATMENT	SECOND TREATMENT
STATION 1	Pretreatment	I	ND	ND
	0 min.	S	ND	0.08
	10 min.	S	ND	trace
	20 min.	S	ND	ND
	1/2 hour	I	ND	ND
	1 hour	I	trace	ND
	6 hour	I	0.017	ND
STATION 2	Pretreatment	I	ND	ND
	0 min.	S	ND	0.019
	10 min.	S	ND	0.061
	20 min.	S	ND	trace
	1/2 hour	I	ND	ND
	1 hour	I	ND	ND
	6 hour	I		ND
STATION 3	Pretreatment	I	-	ND
	0 min.	S	trace	0.23
	10 min.	S	trace	0.28
	20 min.	S	trace	0.20
	1/2 hour	I	trace	ND
	1 hour	I	ND	ND
	6 hour	I	0.018	ND

S : surface water sample
I : integrated depth water sample
ND : non-detectable < 0.005 ug/l
P : pre-treatment sampling
- : sample not taken

Table 12. Residue analysis for sediment samples (ug/kg) taken from Beeton Creek (Site 2)

	FIRST TREATMENT			SECOND TREATMENT				
	PRE-TREATMENT	POST-TREATMENT		PRE-TREATMENT	POST-TREATMENT			
	1-day	6-hr	1-day	1 day	6-hr	1-day	6-day	30-day
STATION 1	trace	ND	ND	ND	ND	ND	ND	trace
STATION 2	ND	ND	ND	ND	ND	ND	ND	ND
STATION 3	-	ND	ND	ND	ND	ND	ND	ND

trace: < 10 ug/kg
ND : non-detectable < 5.0 ug/kg
- : sample not taken

Dispersion throughout the water reduced the residual concentration so that there were only trace amounts accumulated in the sediment (Table 12).

After the second application at Site 2, permethrin residues were detected in surface water only, at all three sampling stations (Table 11). The levels ranged from 0.019 to 0.28 ug/l at application (0 minutes) to 20 minutes after application.

In our study, the permethrin residues in the water and sediment from both creeks were low and disappeared within a short period of time for example, in water, 0 minutes to 6 hours. This observation agrees with other similar studies (Kingsbury and Kreutzweizer, 1979, 1980; Rawn et al., 1982; Rawn, 1981; Sharom and Solomon, 1981). The concentrations and duration of the residues in the water and sediment in our study were significantly less than those required to cause mortalities of aquatic invertebrates (Mulla and Dorwazeh, 1976; Kingsbury, 1976; Mulla et al., 1980; Muirhead-Thomson, 1977; Anderson, 1982; Friesen et al., 1983). Therefore, lethal effects to aquatic invertebrates are not expected to occur in the Bailey Creek and Beeton Creek.

Several researchers have discussed the importance of non-lethal concentrations of permethrin in water and sediment resulting in detachment and downstream drift of certain aquatic invertebrates (Muirhead-Thomson, 1978a,b; Kingsbury and Kreutzweizer, 1979, 1980; Kreutzweizer, 1982). In the studies which involved aerial application, the population of such invertebrates recovered within two months with single applications of 8.8 or 17.5 g/ha (Kingsbury and

Kreutzweizer, 1980). Benthos population recovery took about four months following a single application of 35 g/ha or double applications of 17.5 g/ha, while benthos remained suppressed for up to sixteen months in a stream treated with 70 g/ha (Kingsbury and Kreutzweiser, 1979, 1980; Kreutzweiser and Kingsbury, 1982).

In our study, permethrin concentrations in water were 78 to 99 times lower than concentrations causing catastrophic drift of aquatic organisms. Therefore, sublethal effects to aquatic invertebrates are not expected from these residue levels.

Fish Analysis

Results from the fish sample analysis are shown in Tables 13 and 14. Permethrin concentrations were not detectable, i.e., < 10 ug/kg, in all samples collected before treatment and after treatment.

Spehar et al. (1983) predicted the chronic no-effect concentration for fathead minnows to be 0.66 to 1.4 ug/l for permethrin. In 28-day early life-stage toxicity tests conducted by Hansen et al. (1983) the no-effect level was 10 ug/l for sheephead minnows. Hence, no sublethal effects to fish would be expected to occur from the permethrin residues detected in the Bailey Creek and the Beeton Creek.

Table 13. Residue analysis results for fish collected from Beeton Creek (Site 2)

	Pre-treatment			Post-treatment		
	Number of Fish	Total Wt. (gms)	Residue (ug/kg)	Number of Fish	Total Wt. (gms)	Residue (ug/kg)
Bluntnose Minnow	15	82	ND	14	66	ND
Creek Chub	8	56	ND	8	80	ND
Common Shiner	1	5	ND	6	33	ND
Johnny Darter	25	32	ND	9	18	ND
Log Perch	5	25	ND	10	203	ND
Long Perch	2	6	ND	-	-	-
White Sucker	16	666	ND	9	108	ND

ND : non-detectable < 10 ug/kg.
- : not found

Table 14. Residue analysis results for fish collected from Bailey Creek (Site 1)

	Pre-treatment			Post-treatment		
	Number of Fish	Total Wt. (gms)	Residue (ug/kg)	Number of Fish	Total Wt. (gms)	Residue (ug/kg)
Blacknose Dase	16	45	ND	16	94	ND
Bluntnose Minnow	23	55	ND	6	18	ND
Brassy Minnow	11	42	ND	-	-	-
Common Shiner	33	202	ND	13	90	ND
Creek Chub	33	311	ND	18	124	ND
Johnny Darter	11	22	ND	19	73	ND
Longnose Dase	11	49	ND	-	-	-
Rock Bass	1	13	ND	-	-	-
White Sucker	21	823	ND	-	-	-

ND : non-detectable < 10 ug/kg.
- : not found

CONCLUSIONS AND RECOMMENDATIONS

Permethrin drift from aerial application was measured to a maximum distance of 61 m outside the treatment area. Droplet drift did not enter the adjacent surface water streams at either study site, and would not have entered the streams if wind conditions had been reversed, using the study data. The concentration of the insecticide drifting off site was significantly lower than the amount deposited on the treatment area. The spray drifting off-target was generally made up of droplets < 100 um, and if these droplets could be eliminated, the extent of the drift would be reduced.

Permethrin residues were detected in the water and sediment samples collected after treatment from the Bailey Creek and Beeton Creek; however, these levels would not be expected to cause lethal or sublethal effects to aquatic invertebrates and fish species.

Therefore, a buffer zone of 65 m around sensitive and productive bodies of water would be effective and practical, based on the results of this study.

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APPENDIX I
METHODS FOR PERMETHRIN RESIDUE ANALYSIS OF FILTER PAPER

Scope

This method is suitable for the quantitative determination of permethrin as total isomer content. The limit of detection is 0.1 microgram per filter paper for total isomer content.

Method Summary

Samples of filter paper are extracted with hexane. The total hexane extract is reduced by rotary evaporation to 5 mL. If deemed necessary, a portion of this is cleaned up on a florisil column and analysed using a gas chromatograph equipped with an electron capture detector.

Reagents

(a) Solvents:
Hexane, diethyl-ether, distilled in glass and suitable for pesticide residue applications.

(b) Granular anhydrous sodium sulphate.

(c) Pre-silanised glass wool.

(d) Florisil, 60-140 mesh. ASTM. Activate at 120°C for 24 hours before use.

(e) Stationary Phases for gas liquid chromatography. For total permethrin determination, a non-polar silicone oil, e.g. OVI or OV101 on Gas Chrom. Q, is recommended.

For individual isomer determination, a semi-polar fluoro-silicone oil, OV210 or QFI on Gas Chrom. Q, is recommended.

Safety Comments

The following information is included as an indication to the analyst of the nature of hazards of the reagents used in this procedure. If in doubt, consult the appropriate safety manual (e.g. Chipman Safety Manual) containing recommendations and procedures for handling chemicals, and/or references such as (1) HAZARDS IN THE CHEMICAL LABORATORY, published by the Royal Society of Chemistry, (2) FIRE PROTECTION GUIDE ON HAZARDOUS MATERIALS - N.F.P.A.

Solvents:

Organic solvents can be extremely flammable with harmful vapours. Di-ethyl ether should be handled in a fume chamber and, after use, the bottle should be blanketed with nitrogen to prevent the formation of dangerous peroxide. Bottles of di-ethyl ether should be dated upon receipt and checked for peroxide content after 3 months and before use.

Apparatus

(a) Glass Column: 10 mm I/D x 300 mm, fitted with insertable teflon stopcock and small glass delivery tube.

(b) Gas Chromatograph fitted with Ni 63 electron capture detector and glass column (see G.C. Conditions below).

(c) Rotary evaporator with water bath capable of maintaining a constant temperature of 30°C to 40°C.

(d) Hamilton CR 700 Syringe or equivalent for injection purposes.

(e) 125 mL Round Bottom Pyrex Glass Flask fitted with 24/40 ground glass joint.

(f) 60 mL Ground Glass Wide Mouth Stoppered Bottles fitted with ground glass stopper.

Gas Chromatography Parameters

(a) Total Isomer Determination

(i) Glass column 100 cm x 0.4 cm I/D packed with either 5% OV101 or 3% OV1 on Gas Chrom. Q (100-120 mesh).
Condition the packed column by heating at 270°C for 24 hours with the carrier gas flow rate at 100 mL/min. The detector end of the column is left disconnected to avoid contamination of the radio-active source during conditioning.

(ii) Oven temperature 245°C.
(iii) Injector temperature 260°C.
(iv) Detector temperature 290°C.
(v) Attenuation - variable, according to concentration.
(vi) Carrier gas - Certified Nitrogen - flow rate 90 mL per minute.
(vii) Injection volume - 5 microlitre.

Under these conditions, permethrin gives a single peak at a retention time of 8 - 9 minutes.

(b) Individual Cis and Tans Isomer Determination

(i) Glass column 120 cm x 0.4 cm I/D paced with 5% OV210 or 5% QFI on Gas Chrom. Q (100-120 mesh).
(ii) Other conditions as for total isomer determination, including column conditioning.

The above parameters are based on the use of a Tracor 550 Gas Chromatograph. Depending upon the G.C. used, these parameters could change slightly.

* Note the Ni 63 E.C. detector should be purged at all times with 10 mL/min. certified nitrogen.

Preparation of Columns for Sample Clean-up

Fit a small glass wool plug into the base of a 25 mL glass column and fill with hexane. Add 5 grams of Florisil and then 1 gram of anhydrous sodium sulphate. Allow the solvent to pass through the column, but the column must remain "wet".

Before the column is routinely used for sample clean-up, hexane, usually 5 mL. However, if the permethrin residue in the sample is known to be high, i.e., the filter paper is from the actual plot sprayed, then more hexane will be required.

At this point, 5 microlitres of the foregoing can be injected into the gas chromatograph to see whether there is any background interference. If interference is found, then proceed as in the clean-up procedure below if not, proceed to the gas chromatographic procedure.

Clean-up Procedure

Transfer the 5 mL of extract sample quantitatively to a freshly prepared Florisil column. Allow this to percolate into the column at a rate of 1 mL per minute. Then wash and elute the column as established by the elution patterns previously done. Reduce the volume of the eluate to dryness and make up to a volume suitable for G.C. analysis, i.e., 5 mL.

Gas Chromatographic Procedure

(a) Make repeated injections of 5 microlitres of appropriate permethrin standard at the prescribed conditions. When a constant response is obtained, measure the peak height recorded at the retention time of permethrin and not the concentration of the standard.

(b) Inject 5 microlitres of the sample or clean-up sample solution and measure the peak height of the permethrin peak. In order to obtain accurate quantitative results, peak heights of the standard and the sample should be approximately the same.

(c) It is recommended that the sample be injected in duplicate between two standards.

(d) Calculate the permethrin residue on the filter paper, expressed as micrograms/filter paper.

(e) For confirmation of results, the individual cis and trans isomer determination should be used.

$$\text{Micrograms/Filter Paper} = \frac{P_2}{P_1} \times \frac{S}{R} \times V$$

where P_1 = Peak height of standard
P_2 = Peak height of sample
S = Concentration of standard (micrograms/mL)
R = Recovery factor
V = Volume of sample in mL

Controls and Recoveries

(a) Untreated samples are analysed by the method described to ensure freedom from significant peaks at the retention time of permethrin.

(b) Control recovery experiments are carried out on untreated samples which have been accurately fortified with a known amount of standard permethrin and allowed to dry and stand overnight.

This method has been used successfully to analyse filter papers from aerial application of AMBUSH 500 E.C. in water.

Control recoveries carried out on filter papers fortified with 0.25 ug and 0.50 ug of permethrin gave 96% - 99% recovery.

The limit of detection of the above method using the Tracor 550 was found to be 0.1 ug permethrin (total isomers).

APPENDIX 2

Table A2-1. Weather conditions during the first permethrin application at Site 1

TIME (a.m.)	HUMIDITY (percent)	WIND VELOCITY (mph)	WIND DIRECTION (degrees)
9:37	76	ND	75
9:44	76	ND	90
9:46	76	ND	25
9:47	75	ND	340
9:52	70	ND	325
10:06	65	ND	40
10:12	65	ND	70
10:14	65	ND	65
10:16	65	ND	20
10:17	67	ND	20
10:19	67	ND	60
10:20	67	ND	45
10:28	76	ND	60

ND : non-detectable < 2 mph

Table A2-2. Weather conditions during the second permethrin application Site 1

TIME (a.m.)	HUMIDITY (percent)	WIND VELOCITY (mph)	WIND DIRECTION (degrees)
8:50	92	ND	223
8:55	84	ND	240
9:00	88	ND	320
9:05	84	ND	345
9:10	88	ND	325
9:15	84	ND	335
9:20	84	ND	32
9:25	84	ND	318
9:30	82	ND	329
9:35	81	2	233
9:40	81	3	310
9:45	75	4	323
9:50	74	4	333
9:55	74	3	320
10:00	78	4	293
10:05	78	3	353
10:10	78	3	316
10:15	75	4	315
10:20	72	3	318
10:25	72	4	355
10:30	72	5	335
10:35	72	6	325
10:40	76	6	348
10:45	73	6	338
10:50	64	7	355

ND : non-detectable < 2 mph

Table A2-3. Weather conditions during the first permethrin application Site 2

TIME (a.m.)	HUMIDITY (percent)	WIND VELOCITY (mph)	WIND DIRECTION (degrees)
7:30	92	ND	90
7:34	92	ND	145
7:35	92	ND	95
7:37	92	ND	40
7:44	92	ND	95
7:45	90	ND	175
7:50	90	ND	175
7:55	90	ND	175
7:58	88	ND	175
8:00	88	ND	180

ND : non-detectable < 2 mph

Table A2-4. Weather conditions during the second permethrin application at Site 2

TIME (a.m.)	HUMIDITY (percent)	WIND VELOCITY (mph)	WIND DIRECTION (degrees)
6:20	100	ND	ND
6:25	96	ND	ND
6:30	100	ND	ND
6:35	100	ND	ND
6:40	100	ND	ND
6:45	100	ND	ND
6:50	100	ND	ND
6:55	100	ND	ND
7:00	100	ND	ND
7:05	100	ND	ND
7:10	100	ND	ND
7:15	100	ND	ND
7:20	100	ND	ND
7:25	100	ND	ND
7:30	100	ND	ND
7:35	100	ND	ND
7:40	100	ND	ND
7:45	100	ND	ND
7:50	100	ND	ND
7:55	100	ND	ND
7:57	96	ND	ND
8:00	96	ND	ND
8:05	96	ND	ND
8:10	100	ND	ND

ND : non-detectable < 2 mph

APPENDIX 3

SUMMARIES OF DROPLET CATEGORIZATION

Table A3-1. Site 1 - East of treatment area

Sample in ft. from plot	NMD (uM)	VMD (uM)	D-Max (uM)
Plot	70	260	400
20	52	85	150
40	45	110	150
60	50	100	150
80	70	95	150
100	80	100	150
120	46	80	100
140	50	80	150
160	Ø	Ø	Ø

Table A3-2. Site 1 - South of treatment area

Sample in ft. from plot	NMD (uM)	VMD (uM)	D-Max (uM)
Plot	110	330	500
20	Ø	Ø	Ø

Table A3-3. Site 1 - West of treatment area

Sample in ft. from plot	NMD (uM)	VMD (uM)	D-Max (uM)
Plot	62	250	400
20	54	63	75
40	65	80	100
60	60	110	150
80	80	110	150
100	110	130	150
120	50	100	150
140	60	90	150
160	90	120	150

Table A3-4. Site 1 - North of treatment plot

Sample in ft. from plot	NMD (uM)	VMD (uM)	D-Max (uM)
Plot	43	240	400
20	42	60	100
40	30	44	75
60	27	54	75
80	35	48	75
100	32	38	50
120	Ø	Ø	Ø

Table A3-5. Site 2 - East of treatment area

Sample in ft. from plot	NMD (uM)	VMD (uM)	D-Max (uM)
Plot	50	170	300
20	25	40	75
40	30	58	100
60	60	82	100
80	(25)	(30)	50
100	Ø	Ø	Ø

Table A3-6. Site 2 - South of treatment area

Sample in ft. from plot	NMD (uM)	VMD (uM)	D-Max (uM)
Plot	54	250	400
20	Ø	Ø	Ø

Table A3-7. Site 2 - West of treatment plot

Sample in ft. from plot	NMD (uM)	VMD (uM)	D-Max (uM)
Plot	30	120	400
20	30	65	100
40	30	65	150
60	28	55	100
80	35	65	150
100	35	75	100
120	27	60	100
140	25	35	50
160	20	25	75
180	35	45	75
200	(15)	(20)	(30)
250	Ø	Ø	Ø

Table A3-8. Site 2 - North of treatment area

Sample in ft. from plot	NMD (uM)	VMD (uM)	D-Max (uM)
Plot	75	250	500
20	65	100	150
40	98	180	200
60	50	88	150
80	50	74	150
100	52	150	200
120	30	70	100
140	52	75	100
160	50	55	75
180	45	80	100